An Evaluation of Fly Breeding and Fly Parasites at Animal Farms on Leeward and Central Oahu

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In recent years the development of subdivisions in the rural areas of Oahu has generated an increased volume of complaints to the Vector Control Branch about flies from animal farms. This situation is also common on the mainland. Levels of control formerly obtained are no longer adequate, and the reluctance of farmers to expend money and labor in areas which do not contribute directly to production has necessitated the development of more specific, practical, and inexpensive fly control programs.

Workers such as Legner and Olton (1968) and Axtell (1970) have concluded that an "integrated control" approach is logical for fly control on animal farms. This integrated concept utilizes all compatible means of control including chemical, biological, and cultural control methods. However, our research has shown that much of the basic information required for the development of an integrated fly control program is lacking in Hawaiian literature. The only available references to fly breeding on animal farms in Hawaii are by Illingworth (1923) and Tanada *et al* (1950), which deal with flies in poultry manure. Bohart and Gressitt's (1951) study of the filth-inhabiting flies of Guam is useful, but their findings are not entirely applicable to Hawaiian conditions. Therefore, the present study was initiated to obtain information necessary to develop an integrated fly control program for Hawaii.

The initial phase of this multiple-part study deals with fly breeding and parasite activity on dairy, poultry and hog farms in leeward and central Oahu, and has attempted to answer the following questions: (1) What species of flies and fly parasites are breeding on each type of farm?; (2) Where on the farm are flies breeding?; (3) What methods should be used to survey fly and parasite populations on these farms?; and (4) How efficient are the parasites in reducing fly breeding?

MATERIALS AND METHODS

This study was conducted from March to November 1973, and included six poultry farms, four dairies, and four hog farms located on leeward and central Oahu. Leeward Oahu is warm and dry with rainfall occurring primarily during the winter months, while central Oahu is slightly cooler with moderate rainfall. The two dairies and one poultry farm investigated in central Oahu were at elevations below the usual range of the trade-wind showers. The average temperature and annual precipitation for the past five years was 23.5°C. and 63.5 cm at leeward Oahu, and 23.0°C. and 75 cm at central Oahu.

All poultry farms studied used double-row suspended wire cages containing from four to six double rows of cages per unit. Each unit was housed under a roofed area with open sides for ventilation. The floors under most cages were unpaved and manure deposits formed conical piles beneath them. Watering systems used were either the continuous-flow water trough or the watercup system with a float valve. Water trough systems were sometimes equipped with automatic controls which provided intermittent flow to prevent drainage systems from being inundated.

The hog farms used concrete rearing pens for market pigs and dirt-floored pens for breeders. Since they all used restaurant garbage as the primary feed source, the farms also housed cooking vats and large numbers of 55-gallon steel drums for collecting garbage. Surprisingly, feed preparation areas and rearing pens were always clean. The pens were hosed down at least every other day and feed preparation areas were cleaned daily. Effluent from the pens flowed into ditches that emptied into large, deep, impoundment pits used as combined oxidation and evaporation ponds.

The dairies usually kept their cows in corrals, and dry, gestating cows were kept in pastures whenever they were available. Water troughs were usually discarded bathtubs with the water level controlled by a float valve. Effluent from milking barns flowed into a series of ponds by means of various types of ditches.

Observations on fly breeding were made by probing all possible breeding sites with a trowel. Most larval identifications were made in the field with a 20X hand lens, except for the Sarcophagidae, which had to be reared to adults before identification could be made; and the larvae of *Musca sorbens* Wiedmann and *Musca domestica* Linnaeus, which had to be identified with a microscope because of their similarity. The carrion breeders were reared from chicken carcasses placed in shallow wooden boxes. The larvae were allowed to pupate in a layer of soil and dry manure before being identified and sorted. Only the larger Diptera which had the potential to become nuisances were recorded. The adults of various Otitidae, Sphaeroceridae, and Sepsidae were sometimes present but generally were not pestiferous, either because they did not frequent homes, or because they did not occur in significant numbers.

For parasitization studies, manure containing puparia was placed in water and the floating puparia were picked out with forceps. These were sorted according to species, placed in eight-ounce plastic cups covered with fine mesh organdy cloth, and kept at room temperature for two months. Emerging flies were allowed to die in the containers, while parasites were periodically aspirated and placed in alcohol until they could be identified and counted. The reluctance of most parasites to fly made aspiration possible since they preferred to remain on the sides of the cups. Puparia of species that were difficult to collect in quantity under natural field conditions were obtained by using 30X30X10 cm wooden boxes as pupal receptacles. These boxes were filled with larvae and media (dung or chicken carrion), and exposed to naturally occurring parasites at breeding sites. After a three-day exposure period, puparia were collected and processed in the same manner as field-collected puparia. This box method was also used to determine whether pupae of *M. sorbens* would be parasitized by species not found at dairies, by exposing them at poultry farms where a greater variety of parasites were present.

It must be emphasized that because of different methods of pupal collection used, data on parasitization which we obtained are not strictly comparable. Variables that could not be eliminated were the period of exposure to parasites before pupal collection under natural conditions, and the greater accessibility of the pupae to the parasites in the boxes.

RESULTS

Tables 1 and 2 summarize the species of flies, parasites and the types of farms where they were found. The greatest number of fly species (13) and parasites (9 species) were obtained from poultry farms. Hog farms, although outwardly appearing to be the most unsanitary, yielded only five species of flies and five species of parasites. Dairy farms yielded nine species of flies and eight species of parasites.

TABLE 1. *Fly Species Recovered at Animal Farms*

Family	*Species*	*Hog*	*Dairy*	*Poultry*
Muscidae	*Musca sorbens* Wiedemann	—	X	—
	Musca domestica Linnaeus	X	X	X
	Stomoxys calcitrans (Linnaeus)	—	X	X
	Ophyra chalcogaster Wiedemann	—	X	X
	Fannia pusio Wiedemann	—	—	X
Calliphoridae	*Phaenicia cuprina* Wiedemann	—	—	X
	Chrysomya megacephala (Fabricius)	X	—	X
	Chrysomya rufifacies Macquart	X	—	X
Sarcophagidae	*Tricharea* (= *Sarcophagula*) *occidua* (Fab.)	—	X	—
	Parasarcophaga ruficornis (Fabricius)	—	—	X
	Parasarcophaga argyrostoma (Robineau-Desvoidy)	—	—	X
	Ravinia lherminieri (Robineau-Desvoidy)	—	X	—
	Seniorwhitea orientaloides (Senior-White)	—	—	X
Syrphidae	*Volucella obesa* Fabricius	X	X	X
	Eristalis arvorum (Fabricius)	X	X	X
Stratiomyidae	*Hermetia illucens* (Linnaeus)	—	X	X

Of the five species of Muscidae reared, only *M. domestica* was found breeding on every type of animal farm. At hog farms the principal breeding source was wet accumulated debris along the edges of unlined ditches where effluent flowed into oxidation ponds. Houseflies did not breed in individual dung pats in dirt-floored breeding pens, nor in the concrete rearing pens, since these were frequently washed. At dairy farms, the primary breeding medium was wet manure that collected along the edges of fences, and in spillage of wet cattle feed. Only occasional breeding occurred in individual dung pats. Breeding in poultry farms was in isolated wet spots in the manure cones which were caused either by leaking water systems or by sick birds with wet stools. These wet spots had an amorphous consistency like that of cooked cereal. The larvae of *M. domestica* could be identified in these wet spots by

TABLE 2. *Fly Parasites Recovered at Animal Farms*

Family	*Species*	*Hog*	*Dairy*	*Poultry*
Pteromalidae	*Spalangia cameroni* Perkins	X	X	X
	Spalangia endius Walker	X	X	X
	Spalangia nigra Latrielle	—	X	X
	Muscidifurax raptor Girault & Sanders	X	X	X
	Nasonia (= *Mormoniella*) *vitripennis* Walker	—	—	X
Encyrtidae	*Exoristobia philippinensis* Ashmead	—	—	X
Cynipidae	*Eucoila impatiens* Say	—	—	X
Chalcididae	*Brachymeria fonscolombei* (Dufour)	--	—	X
	Dirhinus luzonensis Rohwer	X	X	X
Diapriidae	*Spilomicrus* sp.	—	X	—
	Phaenopria sp.	—	X	—
Staphylinidae	*Aleochara puberula* Klug	X	X	—

their habit of massing by the hundreds into tight clusters that ranged in diameter from 2.5 to 15 cm.

M. sorbens was found breeding at the dairies only in undisturbed individual dung pats in uncrowded pens or pastures. In normally crowded pens dung pats were trampled and became unfit for breeding. This fly was attracted only to fresh dung pats for feeding and oviposition.

S. calcitrans was recovered primarily at dairy farms and occasionally at poultry farms. Breeding in dairy farms was in wet manure accumulated under fence lines of cow pens, and in wet feed spillage. At poultry farms very light breeding occurred in manure cones under cages, with occasional puparia being collected, along with those of *O. chalcogaster*, in the moist but firm portions of the manure cones.

O. chalcogaster was found at poultry farms in fresh, moist manure on the tips of manure cones under cages of healthy birds with normal stools. Larvae of this fly were once found in old feed spillage at a dairy, but generally this fly was found breeding only at poultry farms. *Ophyra aenescens* Wiedemann was never recovered in this study.

Larvae of *F. pusio* were difficult to find, but puparia were usually collected in the same areas as those of *M. domestica*, which indicated a breeding preference similar to the housefly. The larvae were also found on chicken carrion in late stages of decay.

The hornfly (*Haematobia irritans* Linnaeus) and *Orthellia caesarion* (Meigen) were occasionally reared from cow dung pats but were not considered because they were not of public health significance.

Calliphoridae were found breeding in hog and poultry farms, but not at the dairy farms, even though adults were occasionally observed. *P. cuprina* was found breeding only at poultry farms in chicken carcasses that were not collected after removal from cages. No samples were found in chicken manure, although Tanada *et al* (1950) and Illingworth (1923) reported such breeding.

C. megacephala was found breeding at both hog and poultry farms. Hog farm breeding was in debris accumulated along the sides of effluent ditches and on scum floating on oxidation ponds. Larvae were often observed swimming in oxidation ponds apparently attempting to reach suitable pupation sites. Many puparia were found floating in the water, but apparently were unviable as they failed to produce adults. It was not determined whether puparia found floating in the oxidation ponds resulted from actual pupation in the water or whether they were physically washed into ponds from the ditches. At poultry farms, breeding occurred in uncollected carcasses and in semi-liquid manure under cages.

C. rufifacies was found breeding at both hog and poultry farms. Hog farm breeding was in debris accumulated on the sides of effluent ditches. This fly was found in association with other maggots on whch they were predaceous (Bohart & Gressitt, 1951). The poultry farm breeding source of this species was chicken carrion infested with other maggots.

The Stratiomyidae were represented by the black soldier fly, *Hermetia illucens* (Linnaeus). Although this species was once found in wet feed spillage at a dairy, it is thought to breed almost exclusively at poultry farms, where it was usually found in semi-liquid manure under cages with leaking water cups.

The Syrphidae were represented by *Volucella obesa* Fabricius and *Eristalis arvorum* (Fabricius), both of which were found in all three types of farms. *V. obesa* breeding on hog farms occurred in debris accumulated along effluent ditches and on scum formed on oxidation ponds. At dairy farms breeding occurred on the edges of effluent ditches, while at poultry farms breeding was usually in semi-liquid manure under cages with leaking water. *E. arvorum* breeding at both hog and dairy farms occurred in water along edges of oxidation ponds. Larvae were once found breeding in very wet cow dung under a fenceline, and occasionally occurred in semi-liquid manure under leaking water cups at poultry farms.

The five species of Sarcophagidae recovered showed very specific breeding preferences, but whether these observations were reliable could not be verified because of the small samples recovered. *Tricharea* (=*Sarcophagula*) *occidua* (Fabricius) was found only at dairy farms in individual dung pats, and no samples were ever recovered from accumulated manure. This fly had breeding habits similar to *M. sorbens*. *Parasarcophaga ruficornis* (Fabricius) and *Seniorwhitea orientaloides* (Senior-White) were occasionally found in manure cones at poultry farms. *Parasarcophaga argyrostoma* (Robineau-Desvoidy) was the only species that was found in chicken carrion, while *Ravinia lherminieri* (Robineau-Desvoidy) was found only at dairies in undisturbed dung pats.

Table 3 lists the major nuisance flies and the parasites associated with them at three types of farms. Puparia were collected under natural field conditions, except where designated by the word "Box" which indicates that the puparia were collected in the wooden boxes, as described in the methods section. *T. occidua* was not considered to be a major nuisance fly, but was placed in the table because we believe this species may be diverting part of the parasite activity of *Spalangia endius* Walker away from the puparia of *M. sorbens*. Puparia of these two flies were collected in the same areas as both had the same breeding habits. Observations made after the summer during

TABLE 3. *Parasitization of Major Nuisance Flies*

Host and Source	*E. philippinensis* (gregarious)	*S. cameroni* (solitary)	*S. endius* (solitary)	*S. nigra* (solitary)	*M. raptor* (solitary)	*N. vitripennis* (gregarious)	*B. fonscolombei* (solitary)	*Spilomicrus* sp. (gregarious)	*Phaenopria* sp. (?)	*E. impatiens* (solitary)	*A. puberula* (solitary)	*D. luzonensis* (solitary)	Total Pupae	Parasitized Pupae (%)	Viable Pupae (%)	Dead Pupae (Cause unknown) (%)
	Per Cent of Total Parasites Reared, by Species															
1. *Musca sorbens*																
Meadow Gold Dairy (Pastureland)		0.8	99.2										566	23.1	59.4	17.5
Meadow Gold Dairy (Pastureland – Box)		2.3	87.7		10.0								2151	20.4	23.8	55.8
Dairico Dairy (Corral)			63.2		36.8								194	9.8	40.2	50.0
Dairico Dairy (Corral – Box)		4.3	87.2		6.9							1.6	3062	27.3	22.2	50.5
TOTAL		3.3	88.1		7.7							0.9	5973	23.8	26.9	49.3
Park's Poultry (Under Cages – Box)		80.3	11.5	8.2									1632	21.8	28.2	50.0
2. *Tricharea occidua**																
Dairy Farms (Pastureland)		4.5	77.4		18.1								656	33.7	38.4	27.9
Dairy Farms (Pastureland – Box)		1.2	53.9		43.5				1.4				3055	13.8	33.2	53.0
TOTAL		2.3	62.0		34.7				0.9				3711	17.3	34.1	48.6

3. *Musca domestica*																
Poultry Farms (Under Cages – Box)		1.5	53.1	0.7	44.4							0.3	5192	59.3	5.8	34.8
Dairy Farms		6.8	31.6	0.6	6.7						2.4	51.9	2133	38.6	18.5	42.9
Hog Farms		2.8	63.2		25.5						7.1	1.4	2017	10.5	20.4	69.1
TOTAL		2.6	49.5	0.6	35.9						0.9	10.5	9342	44.1	11.9	44.1
4. *Chrysomya megacephala*																
Poultry Farms (Box – Chicken Carcass)		25.0				10.7	7.1			32.1		25.0	2249	1.3	26.9	71.9
Hog Farms		2.2	82.8		4.3						9.1	1.6	2130	8.7	37.1	54.1
TOTAL		5.1	72.0		3.7	1.4	0.9			4.2	7.9	4.7	4379	4.9	31.9	63.2
5. *Hermetia illucens*																
Poultry Farms													5657	0	94.2	5.8
6. *Phaenicia cuprina*																
Poultry Farms (Box – Chicken Carcass)		5.7	0.1	0.7		4.0				28.5		61.0	8533	19.1	41.4	39.5

*Not a major nuisance fly. (See explanation of Table 3)

TABLE 4. *Parasitization of Minor Nuisance Flies*

Host and Source	*Per Cent of Total Parasites Reared, by Species*												Total Pupae	Parasitized Pupae (%)	Viable Pupae (%)	Dead Pupae (Cause unknown) (%)
	E. philippinensis (gregarious)	*S. cameroni* (solitary)	*S. endius* (solitary)	*S. nigra* (solitary)	*M. raptor* (solitary)	*N. vitripennis* (gregarious)	*B. fonscolombei* (solitary)	*Spilomicrus* sp. (gregarious)	*Phaenopria* sp. (?)	*E. impatiens* (solitary)	*A. puberula* (solitary)	*D. luzonensis* (solitary)				
1. *Chrysomya rufifacies*																
Poultry Farms (Box — Chicken Carcass)	3.5									93.0		3.5	282	10.3	48.6	41.1
2. *Fannia pusio*																
Poultry Farms		46.3	25.6	7.3	20.7								648	12.7	21.9	65.4
3. *Ophyra chalcogaster*																
Poultry Farms		37.9	16.0	11.5						34.6			1615	36.1	—	—
4. *Stomoxys calcitrans*																
Dairy Farms		15.7	30.6		48.1						3.2	2.4	1222	30.8	12.9	56.3
Poultry Farms (Box)		54.2	45.8										209	23.0	12.9	64.1
TOTAL		20.1	32.3		42.7						2.8	2.1	1431	29.6	12.9	57.4

5. *Volucella obesa*																
Poultry Farms													612	0	64.2	35.8
Hog Farms													188	0	71.8	28.2
Dairy Farms													64	0	78.1	21.9
TOTAL													864	0	66.9	33.1
6. *Eristalis arvorum*																
Dairy Farms								100					351	1.1	44.2	54.7
Hog Farms													128	0	38.3	61.7
TOTAL													479	0.8	42.6	56.6
7. *Parasarcophaga ruficornis*																
Poultry Farms		85.7	14.3										13	53.8	15.4	30.8
8. *Parasarcophaga argyrostoma*																
Poultry Farms (Box – Chicken Carcass)							14.4			45.4		40.2	425	22.8	17.4	59.8
9. *Ravinia lherminieri*																
Dairy Farms		37.5	62.5										72	11.1	18.1	70.8
10. *Seniorwhitea orientaloides*																
Poultry Farms		100											9	33.3	44.4	22.3

which these samples were taken showed a seasonal peak in abundance of *M. sorbens* and *T. occidua* at dairies. The abundance of these species peaked during the summer months and remained relatively low during the rest of the year. Puparia collected for another study during November when populations of both species were low, showed a higher parasitization rate of *M. sorbens* than during the preceding summer (Table 3). Only a few adults of *M. sorbens* and practically no *T. occidua* were observed at this time, and dung pat samples yielded only *M. sorbens* puparia. The parasitization rate of *M. sorbens* pupae during this period was 50.6%, with 43.3% dead pupae from unknown causes, and 6.1% viable pupae, from a sample of 1,021. While the increase in parasitization of *M. sorbens* may have been due to a scarcity of available hosts during this period, it is possible that the absence of *T. occidua* may have also contributed to this increase.

Although *M. sorbens* does not breed at poultry farms, puparia of this species were placed at a poultry farm to determine what other parasites not present at the dairies might parasitize it. Because of greater accessibility of the puparia in the boxes, it was assumed that they would be relatively highly parasitized. However, this assumption proved to be incorrect. A possible explanation for these unexpected results was that the parasite population was very low in the dairy pastures and parasites therefore were unable to effectively utilize the more accessible puparia in the boxes.

Table 4 lists other flies collected, and the parasites associated with them, at the three types of farms. The data on *O. chalcogaster* were incomplete because this fly was collected at the beginning of the study when numbers of viable and dead pupae were not being recorded.

Discussion

Breeding Sites. Our data showed that each fly species had a preferred breeding site, and in many instances these sites were very limited. Aside from the differences in the ability of the different species to utilize carrion and dung, the moisture content of the breeding medium appeared to be an important factor affecting population levels. Optimum moisture content for different species ranged from the liquid media utilized by *E. arvorum*; the semi-liquid media preferred by *C. megacephala, V. obesa,* and *H. illucens*; the wet-amorphous media of *M. domestica*; to the moist-firm media of *O. chalcogaster*. In order to correlate moisture content with breeding preferences, the descriptive terms "liquid", "semi-liquid", "wet-amorphous", and "moist-firm" were selected. These terms appear to be adequate for general description, but must be qualified to account for differences in the physical characteristics of the breeding media due to dissimilarities in the constituents of animal feeds. The term "liquid medium" usually refers to water left in oxidation ponds after dung sedimentation has occurred, but it may also refer to any water accumulation in animal dung. The term "semi-liquid" describes animal dung so high in moisture that it appears to have a "soupy" consistency. It is distinguished from the wet-amorphous condition by the thin layer of water that covers the manure. The term "wet-amorphous" refers to manure that is so high in moisture that it will not hold its shape when collected with a trowel. Wet-amorphous is used to describe poultry manure and may not be exactly descriptive of cow manure because of the higher fiber content of the latter. Moist-firm media refers in this paper to poultry manure that is moist but firm enough to hold its shape when collected with a trowel. This type of manure usually occurred on the tips of manure cones under healthy birds.

Another factor which affected fly breeding was the freshness of breeding media. West (1951) claimed that *M. domestica* larvae could not survive in manure that had been "spent." He used this term to describe manure which had passed a stage of fermentation which consumed its nutrients. This preference for freshness was observed in *M. domestica* at the poultry farms, where this species preferred to breed under cages with sick birds which had fresh wet stools, rather than in the more usual mixture of fresh and old droppings wet by leaking water systems. This preference for freshness was very strong in the case of *M. sorbens*. *H. illucens*, *V. obesa*, and to some extent, *C. megacephala*, bred equally well in old dung as long as the moisture content was in the semiliquid range.

Sometimes it was difficult to determine the precise origin of nuisance flies in suburban residential areas. In the case of *M. sorbens* it was difficult to distunguish between flies breeding in dog dung from residential sources and those derived from cow dung at dairies. However, the presence of large numbers of *M. domestica* usually indicated that the source was an animal farm. It has been shown that the predominant fly originating in residential areas on Oahu is *P. cuprina* (Wilton, 1960 and Ikeda *et al.*, 1972), while *M. domestica* is dominant on animal farms. The species originating from animal farms which caused the most problems were *M. domestica* and *M. sorbens* from dairies, *M. domestica* and *H. illucens* from poultry farms, and *M. domestica* and *C. megacephala* from hog farms. The soldier fly, *H. illucens* (which has only recently become the object of complaints), normally is not a problem, but may become abundant under conditions of poor water management, or following treatment of manure with insecticides. The larvae are extremely difficult to kill and often are the only species of fly to survive insecticide applications. This was observed at a poultry farm where the flattened manure cones under cages which had been treated with an insecticide became unsightly masses of larvae 3 to 6 cm deep. This fly is a nuisance to poultry farm workers and others in surrounding areas because of its habit of alighting on people during hot afternoons. Residents in areas around poultry farms may also become alarmed at the sight of hundred of adults resting on foliage during the cool morning hours. Furman, *et al* (1959) found that *H. illucens* larvae suppressed *M. domestica* breeding under poultry cages, but this virtue did not seem to outweigh the obnoxious qualities of this fly under Hawaiian conditions.

Our studies have shown that the primary cause of excessive breeding of nuisance flies has been poor water management, except in the case of *M. sorbens*, which is dependent on fresh undisturbed dung pats in pastures and cow pens. Therefore, in any control program initiated on Oahu, first priority should be given to proper water management. This should also include proper grading of the land to ensure rapid drainage during rainstorms. Observations during the past year indicated that flies (primarily houseflies) usually did not leave the vicinity of the animal farms in great numbers unless population pressure caused by excessive breeding forced them out. The reluctance of flies to migrate permits the breeding of a certain number of flies without the development of a nuisance problem. Observations at a poultry farm near Ewa Beach, Oahu over a one year period indicated that it may be possible to maintain fly populations at a tolerable level for most of the year without any direct control measures other than good water management, healthy poultry, and the action of existing biological control agents. It may become necessary to use insecticides during the rainy season, however. These should be used judiciously as baits or localized treatments rather than general applications over the entire area.

Parasites. Of the 16 species of flies found breeding in animal farms, 14 were attacked by one or more species of parasites. All parasites, with the exceptions of *Eucoila impatiens* Say and *Brachymeria fonscolombei* (Dufour), attacked the flies in the pupal stage. *E. impatiens* and *B. fonscolombei* are larval parasites, the adults of which emerge from fly puparia (Clausen, 1962). No attempt was made to rear parasites from the egg or larval stages since parasites of these stages were not mentioned in the literature. Our discussion of parasite activity will be confined to the flies that are most likely to become the source of nuisance complaints.

Since *M. domestica* has been the primary target for the release of parasites in Hawaii (Davis and Chong, 1968 and Davis, 1971), it was not unexpected that this fly was the most highly parasitized of the species studied. Of the 9,342 housefly puparia collected in this study, 44.1% were parasitized by six species of parasites. The most common housefly parasite at poultry and hog farms was *Spalangia endius* Walker, while *Dirhinus luzonensis* Rohwer, was the most common at dairies. The puparia used in this study were collected in the wooden boxes and were therefore parasitized at a higher rate than normal because of their greater accessibility. High pupal mortality from unknown causes, when combined with pupal mortality caused by parasitization, resulted in only 11.9% of the puparia yielding adult houseflies.

M. sorbens, which was first reported as an accidental immigrant in 1949 (Joyce, 1950), has become the most important nuisance fly on Oahu. On animal farms breeding of this species was confined to the undisturbed dung pats at dairies. Puparia were collected within a 60 cm radius of the center of dung pats, usually 1.3 cm or deeper in compacted soil. This fly was parasitized by four species of wasps, the most common being *S. endius*. Total parasitization at dairies was 23.8% of 5,973 puparia collected. When *M. sorbens* larvae in cow dung were placed in wooden boxes under the poultry cages, *Spalangia cameroni* Perkins was the most abundant parasite reared. The low parasitization rate of *M. sorbens* at poultry farms by *S. endius* indicated that the activity of this species at dairies may have been a matter of host-finding or habitat-finding rather than host-preference. Further experiments with the wooden boxes at dairies seemed to confirm that *S. endius* is probably the most valuable parasite of this fly because of its ability to locate the puparia and to disperse and survive in open fields. The other parasites were abundant only in corral situations where other easily accessible fly puparia were present. A relatively high host-finding ability in *S. endius* was also suggested by results of a cursory survey of *M. sorbens* parasites using fresh dog dung in containers at residences in Aina Haina and Waipahu, Oahu. The samples were insufficient to draw definite conclusions concerning total parasite abundance in these residential areas, but the results demonstrated that *S. endius* was the most consistent and abundant parasite of *M. sorbens* present. Other parasites recovered were *Exoristobia philippinensis* Ashmead from *T. occidua*, and *S. cameroni* from *M. sorbens*.

The soldier fly, *H. illucens*, apparently had some form of natural control which normally kept this species in check, since it was found breeding only in isolated pockets and in small numbers at most poultry farms. This natural control became ineffective however, on farms where insecticides were applied to manure cones for fly control. This was elicited during questioning of two farm managers with adjacent farms. One manager, who had 75% of his manure cones infested, stated that he had discontinued efforts to control soldier flies following repeated failures of chemical applications. The neighboring manager, who had not treated his manure, and previously had no problems with soldier flies, recalled that is was six months after his neighbor first asked him if he had problems with these flies before he noticed his manure cones begin to disintegrate and become flattened by *H. illucens* larvae. Whatever natural control agents of *H. illucens* were present, they definitely were not pupal parasites, since none of the 5,657 puparia collected were parasitized. The puparia were usually found in the dry edges of the flattened manure cones close to their larval feeding site. This fly had the highest percentage (94.2%) of viable pupae of all flies studied.

The pupation sites of *C. megacephala* at hog farms were usually the dry shorelines of oxidation ponds. The larvae did not burrow as deeply as *M. domestica* but they appeared to migrate great distances from their feeding sites to pupate. Attempts to collect puparia from chicken carrion known to have been breeding *P. cuprina* and *C. megacephala* failed to yield either species from loose soil within a 90 cm radius of the carcasses. Despite shallow pupation and easy accessibility, the total parasitization rate was only 4.9% of 4,379 puparia collected. *C. megacephala* was parasitized by eight species of parasites, with *E. impatiens* being the most common at poultry farms and *S. endius* at hog farms.

Puparia of most of the other flies collected were usually found near their breeding site, but the pupation sites of the two syrphids, *E. arvorum* and *V. obesa*, should be mentioned since considerable time was spent in locating these. Puparia of *E. arvorum* were usually found under dry matted grass, rocks, or other debris that afforded shelter along the edges of oxidation ponds. *V. obesa* puparia were not collected at poultry farms even when breeding abundantly, because they were very difficult to locate in the manure. The puparia secreted a white substance on their outer surface that blended perfectly with the color of the chicken manure. They also seemed to produce a glue that adhered the puparia to the medium so that they would not float when immersed in water. *V. obesa* larvae apparently do not burrow deeply to pupate since puparia were usually found on the surface of manure or stuck to the wood in sample boxes. The puparia were easier to locate at dairies due to the white secretion and shallow pupation.

This study revealed no single highly efficient parasite of fly pupae in animal manure, but the combined activity of all parasites appeared to be a significant mortality factor. The extremely high mortality of pupae, from causes other than parasites, often equaled or exceeded mortality from parasitization and was an unexpected result. Possibly our method of keeping the

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